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Title

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Title

Transfer of Basic Sciences Knowledge in a Problem-Based Learning Curriculum

Abstract

Aim: The aim of this study was to evaluate transfer of basic sciences knowledge for clinical application in our BDS programme by exploring the correlations between student performance in integrated dental science (IDS) examinations and applied dental knowledge (ADK) tests.

Methods: Numeric test scores were drawn from summative IDS and ADK assessments undertaken by BDS students spanning six academic years (2013-14 to 2018-19) for two cohorts (2013 and 2014). The data included a total of 13 test scores for each cohort with four IDS tests, taken in Years 1 and 2, and nine ADK tests taken in Years 3, 4 and 5.

Results: The sample included 120 students across both cohorts with 65 females (54%) and 55 males (46%). The correlation coefficients between the successive tests and the combinations of IDS and ADK scores were positive, all being greater than 0.48, and all being significantly correlated ($p<0.001$). Regarding correlation between standardised averages across all IDS tests and all ADK tests performance remained significantly correlated: (2013 cohort: r (53) = 0.667, $p<0.001$; 2014 cohort: r (50) = 0.700, $p<0.001$).

Conclusions: The results of this study show that the students' knowledge of basic sciences correlates with their applied dental knowledge and may offer a predictive value. These findings may be attributed to a PBL curriculum and student-led learning at our school.

Key Words: basic sciences, students, undergraduate dental education, transfer

Introduction

Retention and transfer of basic sciences knowledge into clinical practice remains a challenge in medical education. Cognitive psychology considers transfer as the application of a concept learned in one context to solve a problem in a different context (1). Transfer of basic science knowledge is essential to develop clinical reasoning skills in health professionals' education and is influenced by the curriculum design, learning styles of students and assessment strategies (2). It is a widely held belief that basic sciences (also referred as biomedical or biological sciences) knowledge acquired during the early years of undergraduate medical education is not retained for long and students may struggle to apply it in real life clinical situations (3). Problem-based learning (PBL) curricula are designed to allow spontaneous integration of basic and clinical sciences and facilitate transfer (4). Transfer may be more difficult to achieve in conventional curricula with segregation between basic sciences and clinical subjects. Transfer requires "activation" of prior knowledge to facilitate a conceptual change in the approach of students (5). Moreover, learning is intricately tied to context and surface learning may make it more difficult to apply knowledge in situations which are different to the learning context (6).

Previous medical education research has identified a variety of teaching and learning models to optimise transfer and integration of basic sciences knowledge for application in clinical reasoning and problem-solving skills of students. The use of construct (concept) maps, based on identification of basic sciences concepts underpinning clinical practice and their hierarchical interrelations has been popularised to achieve transfer (7-10). Furthermore, transfer may be facilitated by incorporating a concept in a problem and using a variety of examples to help students learn and apply the concept in multiple contexts (1).

Dental Education literature from the US and Europe shows a trend toward integration of basic sciences and clinical sciences with an overarching aim to enhance the application of basic science principles to clinical decision making and clinical reasoning (11-14). Peninsula Dental School, University of Plymouth, United Kingdom runs a five-year Bachelor of Dental Surgery (BDS) programme based on a student led, PBL curriculum (15, 16). The dental curriculum design at our school is underpinned by the theory of situated learning which views learning as a transformative process which is closely bonded to the context and social interactions (17). Students learning is based on case scenarios of real patients using a problem-solving approach in student-led small group sessions and supported by a PBL facilitator. Student learning is further supported by up to four plenary lectures (one hour each) and two interactive life sciences sessions (three hours each) per week. The plenaries and life sciences sessions are facilitated by the faculty staff as well as regional and national subject experts.

The acquisition and application of scientific knowledge is assessed using two types of assessments, as described below:

In years 1 and 2 of the programme, *integrated dental science* (IDS) assessments are used to test acquisition of biomedical knowledge that underpins contemporary clinical dentistry. Each IDS assessment is based on 60 multiple-choice questions (single-best type) and two diets are administered in each academic year.

In years 3,4 and 5, progress testing is used to assess *applied dental knowledge* (ADK). We have previously published our experience in the use of progress testing in undergraduate dental education (18). Each progress test is based on 100 single-best type multiple choice questions and is benchmarked to the level of knowledge expected of a newly qualified dental graduate. Progress test questions are structured around appropriate vignettes setting the test items within a particular clinical context. This approach is aimed at testing the analysis, synthesis and application of knowledge as opposed to mere factual recall. Three diets of progress tests are administered each year (one test per term) and progress of each student is indexed longitudinally throughout the programme. Not losing sight of the preparedness of students for their transition from basic science to applied knowledge assessments, students sit the ADK tests formatively in year 2, alongside the summative IDS tests.

Both IDS and ADK assessments are summative, and students are required to pass these assessments before progression to the next stage of the programme. Question banks for IDS and ADK assessments have been developed in-house by academic staff and rigorous quality assurance processes are in place. Each test item is scrutinised by subject specialist panels headed by senior academics before inclusion in the bank. Performance of test items is also monitored in pre-test and post-test meetings for each sitting. Standard setting of IDS and ADK assessments is carried out using the Angoff and Hofstee methods, fully supported by an experienced team of psychometricians.

Structured and immediate feedback is provided to the students after each assessment, allowing them to identify gaps in their knowledge and receive support from their academic tutors. Individual feedback to students is provided on the digital student atlas simultaneously with the release of results for each assessment. The feedback includes test scores for each student, their ranking within the cohort, progress in relation to previous sittings and details of correct, incorrect and “don’t know” responses. Moreover, students receive a short statement outlining the main learning outcome being addressed by each test item. The students are supported by designated academic tutors throughout and are able to receive additional feedback on their performance in IDS and ADK assessments. All academic tutors as well as PBL tutors are required to have a formal teaching qualification and the Dental School provides additional training annually including sessions on equality and diversity; unconscious bias; data protection and supporting students with disabilities.

The aim of this study was to evaluate transfer of basic sciences knowledge for clinical application in our BDS programme by exploring the correlations between student performance in integrated dental science examinations and applied dental knowledge tests.

Methods:

Ethics Approval for the study was granted by the institutional ethics committee (Reference Number 16/17-695). It was an exploratory study to determine correlations between Integrated Dental Science and Applied Dental Knowledge assessments. The study was carried out at a Dental School in the South West region of England.

Data collection was based on numeric test scores drawn from summative IDS and ADK assessments undertaken by BDS students spanning six academic years (2013-14 to 2018-19) for two cohorts (2013 and 2014). Data for students who did not follow a normal progression pathway (i.e. had to repeat a year or interrupted their studies) were excluded from the analyses, along with any students who had missing data for more than half of either the IDS or ADK tests. The data included a total of 13 test scores for each cohort with four IDS tests, taken in Years 1 and 2, and nine ADK tests taken in Years 3, 4 and 5. The sample included 120 students across both cohorts with 65 females (54%) and 55 males (46%).

Data analyses were carried out using R 3.5.0 (R Core Team, 2018), with the *lme4* (2015) package. Each test percentage score was standardised within the cohort group and averages were calculated for each year of study, for all IDS tests and for all ADK tests, with any averages being re-standardised.

To determine the relationship between the scores for the IDS and ADK assessments correlation coefficients were calculated for a number of different pairs across the individual test scores and averaged test scores (column 1, Table 1). From the findings of the correlations, some of the relationships were graphically represented in scatterplots and linear regression models were constructed to further evaluate the relationships to determine whether IDS scores are a predictor of ADK scores. These models controlled for variation by demographic factors, cohort group and included random effects for the clustering of student scores.

Results

The correlation coefficients between the successive tests and the combinations of IDS and ADK scores were positive, all being greater than 0.48, and all being significantly correlated ($p<0.001$). At an individual test level, the transition from IDS test to ADK test (pair IDS2.2:ADK1) showed one of the weaker relationships (2013 cohort: r (60) = 0.529, $p<0.001$; 2014 cohort: r (50) = 0.498, $p<0.001$) but was still highly significant (Table 1).

At year of study level, the correlation between the average year scores for the final year of IDS (Y2) to the first year of ADK (Y3) (pair Y2:Y3) strengthens (2013 cohort: r (60) = 0.654, $p<0.001$; 2014 cohort: r (53) = 0.662, $p<0.001$).

Regarding correlation between standardised averages across all IDS tests and all ADK tests performance remained significantly correlated: (2013 cohort: r (53) = 0.667, $p<0.001$; 2014 cohort: r (50) = 0.700, $p<0.001$). The relationships between the IDS and ADK scores for each student (point) in each cohort (colour), along with the lines of best fit (coloured by cohort) are shown in Figures 1-3.

Separate regression models were used to predict ADK performance from IDS performance after controlling for demographic variables. For the 2013 cohort both Y2 IDS and average IDS performance were significant predictors of Y3 ADK performance (Y2 IDS: R^2 = 0.586, F(5,55) = 15.57, p<0.001; Average IDS: R^2 = 0.619, F(5,55) = 17.90, p<0.001) [Figures 1 and 2]. Average IDS performance was also a significant predictor of overall average ADK performance (R^2 = 0.606, F(5,49) = 15.05, p<0.001) [Figure 3].

For the 2014 cohort Y2 IDS and average IDS performance were significant predictors of Y3 ADK performance (Y2 IDS: R^2 = 0.518, F(6,43) = 7.69, p<0.001; Average IDS: R^2 = 0.569, F(6,43) = 9.44, p<0.001) [Figures 1 and 2]. Average IDS performance was also a significant predictor of overall average ADK performance (R^2 = 0.656, F(6,42) = 13.37, p<0.001) [Figure 3].

Discussion

The purpose and value of basic sciences in healthcare curricula is subject to debate and different views on this issue have been advocated in the literature (19). One view is that the basic sciences play a fundamental role in gaining an understanding of the normal structure and function of the human body and equip the learners to apply this knowledge in clinical situations to recognise pathological changes as a first step in the management of disease. Proponents of this view believe that undergraduate education needs to provide a framework for integration of basic sciences with clinical topics and facilitate scaffolding of this learning (20, 21). However, others have hypothesized that basic sciences and clinical knowledge represent two different worlds with distinct modes of reasoning and different ways of structuring knowledge (22). For example, correlating the clinical presentation of a disease to develop a diagnosis is different from explaining the cause of the disease. According to this hypothesis, complete merger of basic sciences into clinical knowledge can potentially dilute the focus and quality of basic sciences. Notwithstanding the merits of either approach, healthcare educators need to aim for a balanced approach to provide an applied context to students learning basic sciences.

Students often find it difficult to apply their knowledge in clinical situations which are different to the learning context (23). Situated learning addresses this problem through social interactions and legitimate peripheral participation to enhance learning in a variety of environments and contexts. Through participation, active engagement and assuming increasing responsibility, the learners acquire the roles, skills, and values of the community. Moreover, the transfer is facilitated by a problem-solving learning approach (24, 25). The results of this study show a significant correlation between student performance on basic science assessments with assessments of applied clinical knowledge, which provides evidence of transfer. The basic science results were a significant predictor of applied knowledge results in the study population. These findings may be attributed, in part, to the student led, PBL curriculum design at our institution. The students learn their basic sciences in the context of clinical scenarios in PBL cases which facilitates deep learning and the application of knowledge. Moreover, dental students at our school gain clinical exposure to patients from Year 1 and our previous work has shown that early clinical exposure is useful in providing a context to theoretical learning and application of knowledge (26). Whilst our results may not appear surprising, this research goes some way to further validate our spiral curriculum approach within a PBL curriculum (27).

The results of our study are in accord with previous research on dental students which shows that integration of basic and clinical subjects may improve the application of knowledge . Learning activities aimed at providing a clinical context and application of basic sciences knowledge to patient management improve the comprehension of the subject concepts and increase motivation levels of the students (28). A study on dental students reported that improved diagnostic accuracy of dental students when basic sciences were integrated with clinical subjects compared to their peers who were taught using a segregated model (29). Previous research on medical physicians and undergraduate students has also shown that basic science knowledge is activated in expert diagnostic reasoning through its relationship with clinical knowledge (30). Finally, basic science knowledge may also be predictive of performance in the licencing examination for medical graduates (31).

This study has a few limitations: Firstly, the sample was restricted to a single programme; secondly, due to the small sample size, further analyses to identify the impact of demographic factors were not feasible. Future studies involving multiple institutions may help to address sample-size issues, allowing more comprehensive analyses to explore correlations between basic sciences and clinical knowledge assessments. Moreover, qualitative methods need to be employed for a deeper insight into the perceptions and experiences of the stakeholders including teachers and students.

Conclusion

This is one of the few studies which evaluates the transfer of basic sciences knowledge of dental students in a problem-based learning curriculum and the results show that student-performance on integrated dental sciences assessments was significant predictor of applied dental knowledge results in the study population. Notwithstanding the limitations of the study, the results validate previous studies on medical and dental students.

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Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions

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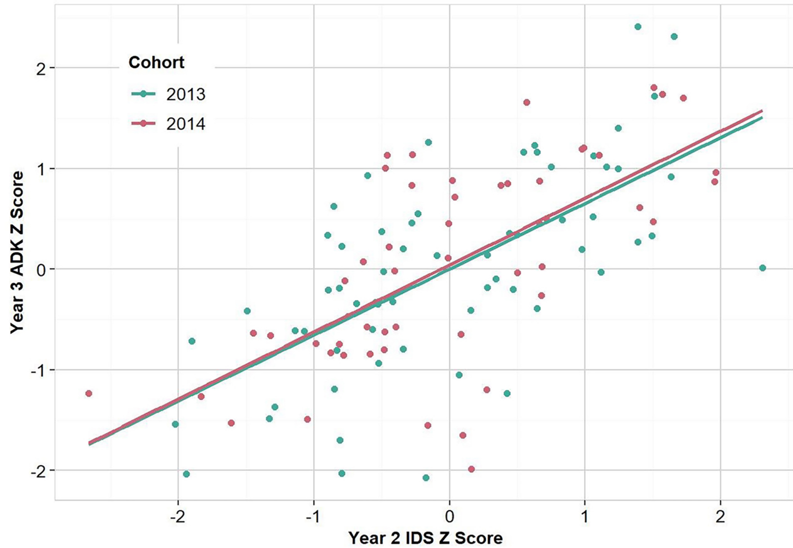
Table 1: Correlation coefficients between IDS and ADK test scores by cohort

	2013 cohort			2014 cohort		
Pair	df	r	p	df	r	P
IDS1.1:IDS1.2	60	0.712	<0.001	50	0.582	<0.001
IDS1.2:IDS2.1	59	0.550	<0.001	50	0.485	<0.001
IDS2.1:IDS2.2	59	0.680	<0.001	50	0.594	<0.001
IDS2.2:ADK1	60	0.529	<0.001	50	0.498	<0.001
ADK1:ADK2	60	0.710	<0.001	54	0.671	<0.001
ADK2:ADK3	60	0.727	<0.001	54	0.548	<0.001
ADK3:ADK4	53	0.681	<0.001	53	0.520	<0.001
ADK4:ADK5	52	0.641	<0.001	54	0.724	<0.001
ADK5:ADK6	52	0.659	<0.001	54	0.489	<0.001
ADK6:ADK7	52	0.596	<0.001	54	0.540	<0.001
ADK7:ADK8	53	0.507	<0.001	55	0.508	<0.001
ADK8:ADK9	53	0.528	<0.001	54	0.664	<0.001
Y1:Y2	60	0.752	<0.001	50	0.644	<0.001
Y2:Y3	60	0.654	<0.001	53	0.662	<0.001
Y3:Y4	54	0.802	<0.001	54	0.700	<0.001
Y4:Y5	53	0.840	<0.001	49	0.740	<0.001
Y2:ADK1	60	0.604	<0.001	50	0.752	<0.001
IDS:ADK1	60	0.600	<0.001	50	0.582	<0.001
IDS:Y3	60	0.693	<0.001	50	0.599	<0.001
IDS:ADK	53	0.667	<0.001	50	0.700	<0.001

df=degrees of freedom, r=correlation coefficient



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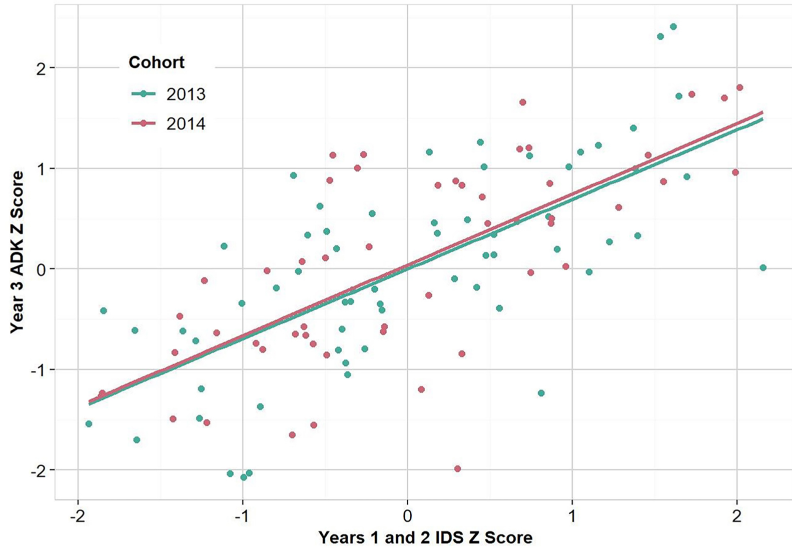

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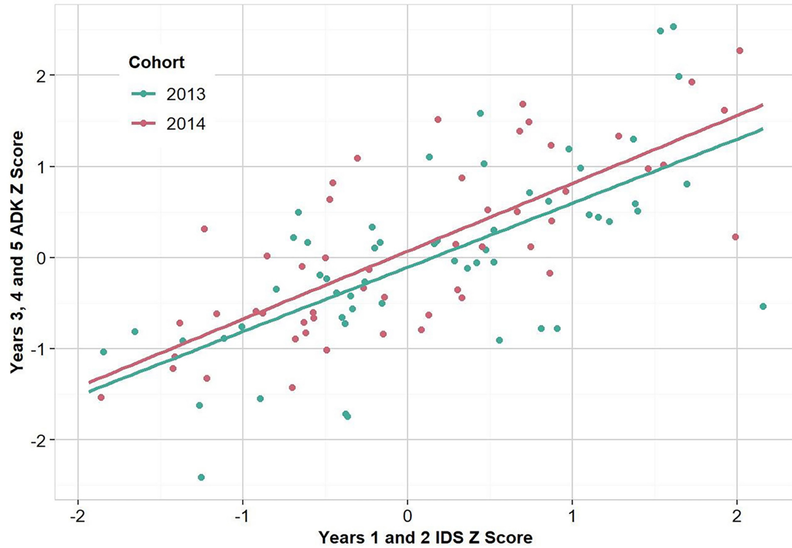

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